IMPROVING INTEROPERABILITY TROUGH GATEWAYS AND COTS TECHNOLOGIES

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***Abstract* – As the Software Defined Radio (SDR) terminals evolve the complexity of these terminals and the waveforms they host get more and more complicated. The network capabilities and the new features introduced in such terminals (as SNMP) shorten the differences between a traditional web approach and SDR-based networks.**

The typical command and control headquarter has evolve during the last few years, were the hardware based terminals has been replaced for SDR terminals working together seamlessly in different network configurations supporting voice and data and operating both in broadcast and point-to-point mode.

As new systems have to coexist with legacy equipment most of the actual deployments suffers from interoperability problems. The situation gets worse in coalition or Military Operations Other Than War (MOOTW) because waveforms from different nations or military and civil or public safety equipment have to interoperate.

The paper proposes the idea of Information Gateway, a system in which a set of waveforms can be loaded to enable communications among different communications network.

***Index terms* – SDR, SCA, Security, Black Red separation, Software Radio, Signal Processing**

1. INTRODUCTION

According to [1] [2], Software Defined Radio (SDR) refers to the capabilities of the Radio Systems to be upgraded via software updates or reconfigurable through software commands. The adoption of these technologies minimizes the number of required terminals while increases their lifetime. The standard born under the umbrella of the JPEO JTRS program and from 1999 until nowadays the evolution of the military communications has been based on the SDR architectures, the JPEO JTRS SCA [3] become the de facto standard.

Nowadays the tactical communications deployment configurations have greatly changed their requirements and CONOPS (Concepts of Operations). A typical deployment requires different kinds of communications equipment, connected to different kinds of networks depending on:

- Throughput and topology requirements
- LPD (Low Probability of Detection) / LPI (Low Probability of Interception) requirements
- Anti-jamming and resilience capabilities
- High speed capabilities
- Legacy systems

This situation has provoked the co-existence of multiple proprietary solutions that hardly interoperate among them. The figure below shows the JTRS Inc 1 deployment [4] where all the different networks and Waveforms are depicted:

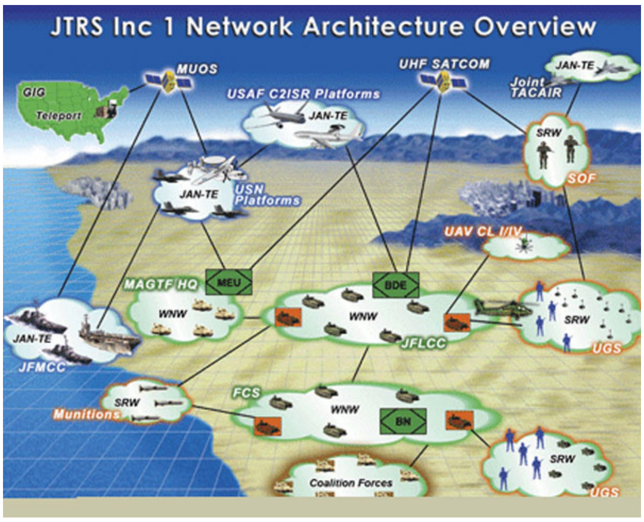

Figure 1. JTRS Inc 1 Network Architecture

Dennis Bauman [4], Joint Program Executive Officer for the Joint Tactical Radio System, stated that SDR and SCA capabilities are the main enabler of the final GIG scenario.

The US DoD [5] enforces this scenario by highlighting: "The Global Information Grid (GIG) must be designed and optimized to support warfighting functions of advantaged and disadvantaged users, to include mission partners, across the full range of military and National Security operations in any operational environment. The GIG must also be resilient and able to support the missions despite attacks by sophisticated adversaries"

Working in parallel to the US DoD GIG, the NATO NNEC [6] initiative proposes the ability to federate various capabilities at all levels, military (strategic to tactical) and civilian, through an information infrastructure.

The introduction of new information sources like sensor networks or UAV's, or the interoperability with civilian or public safety equipment in Military Operations Other Than War missions', enforces more the idea of an over-connected network.

It's clear that if the requirements and the CONOPS change, the technology has to change accordingly. The Joint Inter-departmental and Multinational (JIM) operations have created the requirement to exchange tactical information between different government departments and international collaboration partners. These communication channels are mostly over the air within a designated operational space.

The adoption of indigenous data link technologies has allowed departmental or national control of tactical data exchange but has prevented interoperability for greater JIM operations.

2. INTEROPERABILITY CONSTRAINTS

Numerous commercial and propriety RF waveforms are used by government departments or collaboration partners. A few such waveforms could include:

- TETRA: National Security Services
- Kenwood: Government Departments
- Vertex: Government departments
- Link-11 (Protocol): Military collaboration partners
- Link-16 (Protocol): Military collaboration partners
- Link-22 (Protocol): Military collaboration partners

It is also expected that in future commercial communications networks shall be utilized more freely by defense forces as threats move towards requirements for rapid and flexible deployments in the context of border protection, disaster relief and event security operations.

In this context, military and government interoperability to commercial networks shall be a valuable resource to handle broadband information exchange requirements such as real-time video. Waveforms that might be applicable in this context could include;

- Wifi (IEEE 802.11) : 2.4 GHz
- WiMAX (IEEE 802.16) : typical 5 GHz
- GPRS/EDGE/HSDPA/LTE : 800 – 1.2 GHz
- L-band Satcom : 1-2 GHz
- S-band Satcom : 2-4 GHz

The concept of an RF interoperability gateway has been identified as a future technology that could be employed to facilitate RF interoperability between these different waveforms. This gateway will have to be able to be reconfigurable to accommodate different waveforms.

3. GATEWAY USAGE FOSTERING INTEROPERABILITY

3.1 History of Communication Technologies

Around the 1980s the theories of Jean Baptiste Joseph Fourier (1768-1830) was re-visited and it was found that Fourier also developed a Discrete Fourier Transform that allowed for the development of digital radio waveforms.

This lead to research in analog-to-digital and digital-to-analog convertors as well as digital signal processing technologies.

Digital Signal Processors (DSPs) were developed. The DSP is a specialized microprocessor with an architecture optimized for the fast operational needs of digital signal processing. The first "true" single-chip DSP was made public in early 1980 by Bell Labs. DSPs were also re-programmable, which allowed for ease of redesign.

Field-Programmable Gate Array (FPGA) was first researched in the 1980s as Integrated Circuits (ICs) designed to be configured by the customer or designer after manufacturing—hence ”field-programmable”. The FPGA configuration is generally specified using a Hardware Description Language (HDL). FPGAs can be used to implement any logical function that an IC could perform. The ability to update the functionality after shipping, partial re-configuration of the portion of the design and the low non-recurring engineering costs relative to an IC design (notwithstanding the generally higher unit cost), offered advantages for many applications.

DSPs and FPGAs were in wide commercial use by the mid 1990’s and continue to be a critical part of telecommunications equipment and Software Defined Radios (SDR) worldwide.

The availability of DSP’s and FPGAs and computers sparked research into new radio development philosophies. This work brought to life Software Defined Radio (SDR) in the late 1990s. A SDR system is a radio communication system where components that have typically been implemented in hardware (e.g. mixers, filters, amplifiers, synthesizers, modulators/demodulators, detectors, etc.) and were instead implemented by means of software on a computer or embedded computing device (DSPs, FPGAs etc).

The rapidly evolving capabilities of digital electronics (DSPs, FPGAs, Microprocessors) has made many waveform development concepts that has only been theoretically possible a practicality. A typical depiction of a SDR waveform is provided in the figure below:

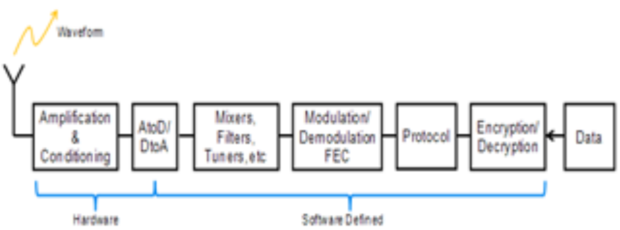

Figure 2. Functional SDR radio

An implementation illustration of SDR can be simplified to the block diagram below:

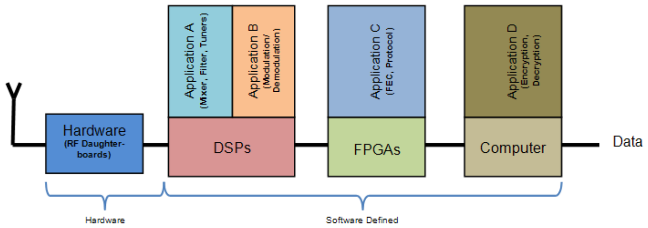

Figure 3. Implemented SDR radio

Current SDR radio implementations are specific to a waveform and current research is aimed at finding common means that would allow waveform portability to allow re-configurability of common radio hardware with different waveform implementations.

3.2 Current trends for waveform re-configurable SDR

Based on current trends in software communications architecture, new approaches to radio communications are being researched. These approaches require new skills base in radio development that transitions from a previously hardware focused approach to a software focused approach.

Current trends are predominantly based on the United States developed Software Communications Architecture (SCA) framework. This approach was motivated by a need to manage and integrate a number of different “stovepipe waveform” radios for Joint, Interdepartmental and Multinational (JIM) operations.

Software Communications Research aim to establish a common radio architecture that can facilitate interoperability for different environments that include handheld, vehicular, dismounted, fixed maritime and airborne communications.

The required architecture must be able to execute multiple radio frequency waveforms from as low as 0.5 MHz in the High Frequency (HF) domain up to frequencies in the C-band (4-8GHz) for satellite communications.

3.3 Information Gateway Technology

Within the scope of JIM operations, different organizations utilize different data models to represent the information applicable to their domain.

A CSIR (Council for Scientific and Industrial Research) example can be an information gateway technology that has been required to integrate tactical communications information of between tactical, mobile and static communications infrastructures.

These gateways perform information conversions. Within this context the information gateways could perform information translations from different message sets like NATO M-Series, J-Series or VMF message sets to commercial message sets.

Preliminary experiments have been performed in this respect through creating an experimental information gateway integrated to numerous platforms communication infrastructure.

This approach leans on the development of reference elements. A reference of each platform is included into the gateway architecture allowing data conversions to be made that facilitates interoperability.

Figure 4 illustrates the information interoperability gateway concept as it has been experimented with to date.

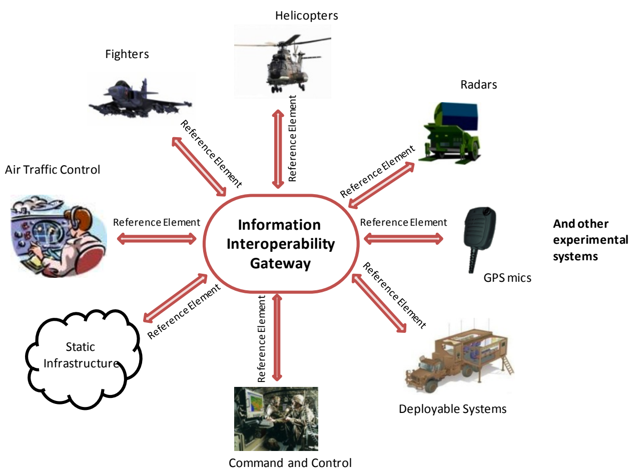

Figure 4. Information Interoperability Gateway concept

Within this context it is foreseen that the information interoperability concepts will be able to support flexible and scalable networks that allow for range extension functions through mobile and static DICI.

3.4 Future Interoperability Gateway concept

Taking the information and RF interoperability gateways into account, it can be seen that a configuration, as illustrated in Figure 5, would be able to provide an interoperability node in communications networks where interoperability for JIM operations can be fully facilitated.

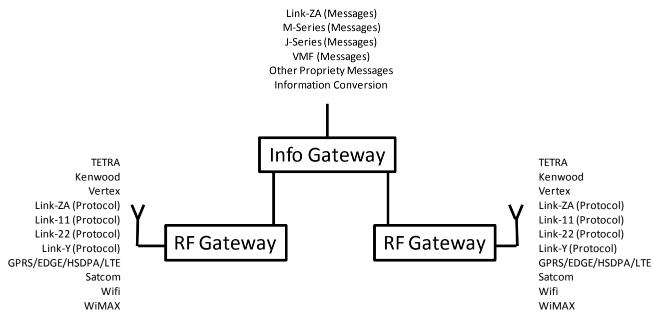

Figure 5. Future interoperability gateway node

A typical communications network that this technology would be able to support is illustrated in Figure 6.

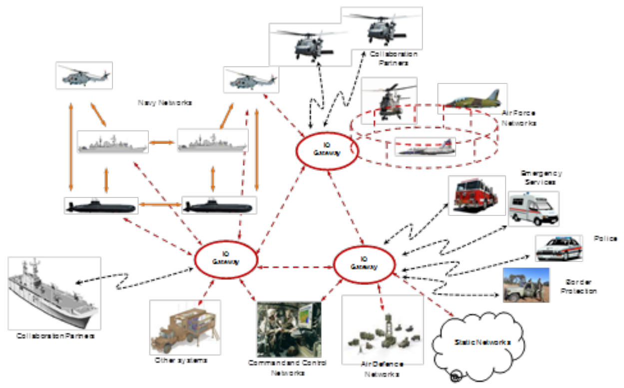

Figure 6. Typical future network

4. A SCA BASED INFRASTRUCTURE

4.1 The SCA stack implementation

The SCA comes to this environment as a catalyzer for the information gateway. The final solution has to provide a different set of waveforms running simultaneously in the same equipment to allow interoperability among different communications networks. And is exactly here where the SCA can help the development.

The SCA provides a common framework for developers abstracting the underlying hardware and unifying efforts. Although the SCA is not specifically designed to support communications waveforms, the usage of the JTRS API's confers to the developer the ability to implement highly portable communication applications. The teams are able to develop different waveforms and jointly deploy them into the information gateway. The picture below shows this set up:

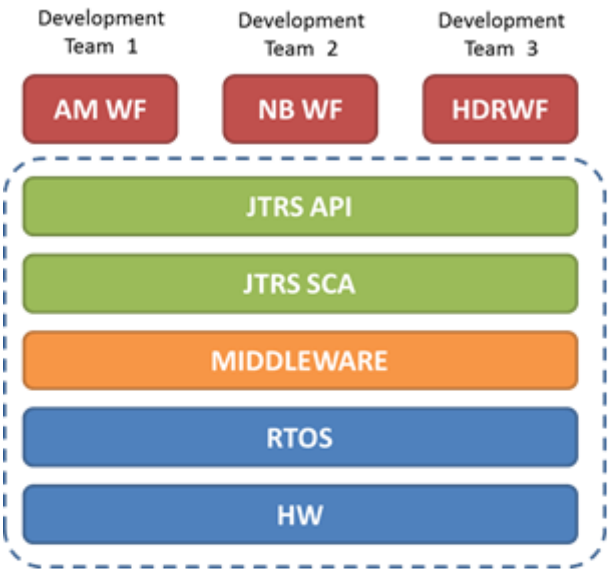

Figure 7. WF development team infrastructure

Each waveform development team can have its own SCA stack, from the JTRS API implementation to the HW, but if the compliance is maintained, the portability effort to the target environment, in this particular case the Information Gateway, is reduced to the minimum. Going deeper in this idea, the teams can develop each waveform simultaneously, reducing dramatically the time to deploy of the nodes.

4.2 Success History

In [7] [8] it's shown how an out-of-the-box Android smartphone can be used as an information gateway hosting JTRS SCA based public safety waveforms: AM, FM and APCO-P25.

The picture below shows the installation diagram for establish the communication among the different devices:

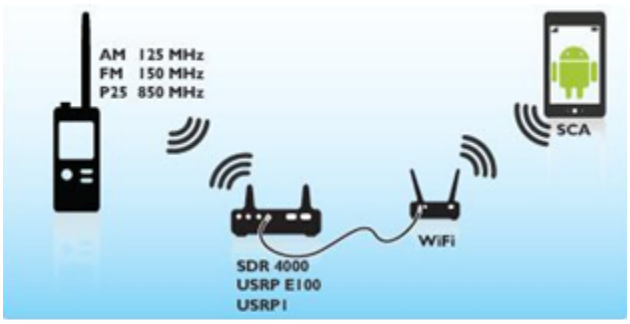

Figure 8. Android Gateway infrastructure

The objective of the scenario was to prove successful communications between the commercial handset and the smartphone. Thus, the entire SCA stack, including the CRC's Core Framework [8] and the OIS's CORBA middleware [9] was installed in the Android smartphone. The three SCA compliant waveforms were installed also in the phone. It's worth to mention that the waveform performed the signal processing required for the communication (vocoder, modulator, squelch tone injector, etc.), but for physical reasons (a commercial phone is not able to transmit in the same frequency range as the handsets), the phone had to be connected to a RF device.

This configuration allows the user to receive in either one of the waveforms and select another one for transmission purposes achieving the desired functionality for the information gateway. The figure below exemplifies the usage of this early development:

Figure 9. Android Gateway information usage

This solution not only demonstrates the suitability and the success of the SCA standard small form factor devices, but also pulls down the myth of CORBA performance.

It can be true that some of the CORBA solutions available in the market are not ready for its deployment on small form factor devices, but this demonstration proves the standard is not the problem, the problem is the implementation.

There were two different CORBA implementations on the Android smartphone running smoothly in a single ARM processor.

4.3 The usage of COTS to streamline the solution

The scenario depicted in the previous chapter it wouldn't be possible without the usage of COTS solutions. Most of the software installed in the Android smartphone was acquired from COTS suppliers, demonstrating the suitability and robustness of this kind of solutions.

The SDR development has matured enough to trust on the solutions provided by third party suppliers. The process to test the hardware of the radio equipment has evolved for a long period of time to assure different levels of functionality. Although this process is starting in the software arena, for most of the critical developments a truly certification process has been achieved.

This situation fosters and enables the possibility of using software components from different vendors and integrates them seamlessly into the ready-to-deploy equipment.

Middleware or Core frameworks are now consider at the same level of more traditional software components, like the Real Time operating systems.

5. Conclusions

The paper has depicted the interoperability problem present in nowadays military communications deployments. This problem gets worse when coalition or heterogeneous forces come into play.

In order to solve this problem, the paper has presented the concept of information gateway. This solution will only be usable if its time to deploy is shorten as only make sense if the solution is applied today.

Fortunately, development of the different waveforms and the Information Gateway Platform Software can be streamlined with the usage of COTS solutions. Nowadays, and thanks to the existence of Certification Labs, these kind of solutions are mature enough to be used in deployed-on-the-field equipment, assuring the same robustness and functionality than in-house developments.

A first approach of this kind of solutions has been presented, using an Android smartphone hosting the SCA environment and allowing interoperability among the main public safety networks.

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